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Application of Carbon Electrode with Polymer Electrolyte for Electric Double Layer Capacitor

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INTRODUCTION

The electric double layer capacitor(EDLC) has been widely used for memory back-up devices in many fields of electric equipment. The EDLC is an energy storage system with short charge time. Specifically the high-rate charge/discharge of EDLCs is possible with excellent rechargeability[3]. The application of the polymer electrolyte(PE) to EDLCs can lead to thin film cells and high reliability without leakage of liquid components. Thin film EDLCs aim at new market, such as smart card, electric vehicle and load leveling[4]. Polymer electrolyte offered the interesting possibility of developing new type of capacitor, so-called EDLC. In recent years, there has been increasing interest in thin film EDLC because of its wide technological application. The thin film EDLC consists of polymer electrolyte sandwiched between two high surface area blocking electrodes. The thin film EDLC has attracted attention for it has the advantage of ease fabrication for small devices and high energy density. The electrical energy of EDLC is stored based on the separation of charged species and electrolytic double layer across the interface of electrode and electrolyte.

This work means the research and development of thin film EDLC with carbon composite electrodes and polymer electrolyte which have high energy density for thin film electric double layer capacitor. And we investigate performance of a thin film EDLC based on the activated carbon(AC)/carbon composite electrode and poly(vinylidene fluoride)[PVDF]-based polymer electrolyte.

EXPERIMENTAL

Composite electrode was prepared by mixing activated carbon(AC, specific surface area 1200m²/g, Aldrich Co.) with LONZA carbon(KS-6). The AC/KS-6 was mixed with kynar 2801/N-methyl-2-pyrrolidone(NMP) solution. We prepared composite films with 5wt.% KS-6. The composite electrode films were prepared by coating this slurry on Al foil current collector. After solvent evaporation, they were vacuum-dried at 110°C for 6h. The electrode was 2 X 2 cm² in size, and the thickness of film was 25 μm. Polyvinylidene fluoride-hexafluoropropylene(PVDF-HFP, Eif Atochem, Kynal 2801) was dried under vacuum at 60°C for 20h. LiClO₄(Aldrich Co.) was dried under vacuum at 110°C for 20h before use. Propylene carbonate(PC) and ethylene carbonate(EC) were purchased from Aldrich Co. LiClO₄ was dissolved in PC-EC solution which was dried by storing it over molecular sieves. The mole ratio of PC-EC-LiClO₄ was PC₁₀EC₁₀LiClO₄, and 25wt.% PVDF-HFP. The liquid electrolyte solution was homogeneously mixed by stirring. The polymer electrolyte film was prepared by heating at 115°C for 15min. The thickness of electrolyte film was 100 μm. Preparation and test of cells were carried out in argon-filled glove box.

RESULT AND DISCUSSION

Cyclic voltammograms of the capacitor cells at 20mV/sec scan rate are shown in Fig. 1. The cyclic voltammograms that charge and discharge behavior between the AC electrode and the electrolyte occurs at a

constant rate in the voltammogram for the AC and 5wt.% KS-6 addition electrodes, the peaks of redox and oxidation not observed for EDLC cells.

The charge/discharge cycling was carried out between 0V and 3V with current density of $1\text{mA}/\text{cm}^2$ at room temperature. The charge/discharge curve was linear. The discharge capacitance of AC composite with 5wt.% KS-6 in 1st and 10th cycles was 100 and $94\text{mF}/\text{cm}^2$ at current density of $0.1\text{mA}/\text{cm}^2$. Also, the discharge capacitance of AC electrode was 80 and $78\text{mF}/\text{cm}^2$. The first discharge capacitance of AC electrode capacitor was 80 and $59\text{mF}/\text{cm}^2$ at the 0.1 and $1\text{mA}/\text{cm}^2$, respectively. In addition, the first discharge capacitance of AC composite with 5wt.% KS-6 capacitor were 100 and $76\text{mF}/\text{cm}^2$. The capacitance of AC composite with 5wt.% KS-6 capacitor was larger than that of AC capacitor without KS-6. This result is interesting. We suspect that the capacitance of EDLC system with porous electrode and polymer electrolyte may be affected by internal resistance of EDLC electrode.

The leakage current increased as the applied voltage increased. The increment of leakage current may be due to the decomposition of remaining water in polymer electrolyte. The capacitance of AC composite EDLC of working voltage of 4V was 13 and $8.2\text{F}/\text{g}$ at cycle of 1 and 50, respectively. First coulombic efficiency was 48%. This difference of the discharge capacitance reached almost 40%. But fading in capacitance of EDLC with cycling of working voltage of 2V and 3V was much lower. The cut-off voltage of stability and high coulombic efficiency of AC composite EDLC with polymer electrolyte was 3.0V.

The coulombic efficiency of EDLC at discharge process of 1 and 1000 cycles were 96 and 100%, respectively. The very slow decrease of capacitance with cycling may be decomposition of polymer electrolyte. From these results, we can say that AC composite EDLC with 5wt.% KS-6 content delivers good capacitance and stability with cycling.

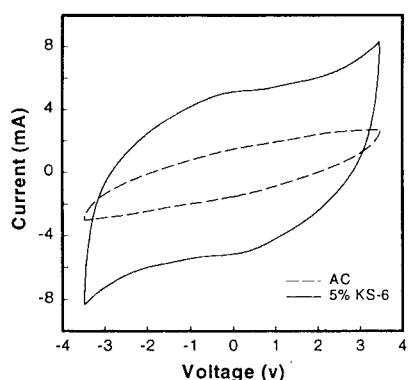


Fig. 1 Cyclic voltammograms of EDLC cells.

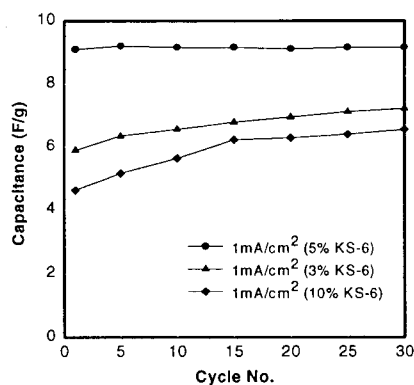


Fig. 2 Discharge capacitance of EDLC cells as a function of addition ratio.

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